Claims

1. An electrochemical device comprising:

an anode constructed of a material such that the anode is a chemically rechargeable anode; and

a source of fuel exposable to the anode.

2. The device of claim 1, further comprising a source of a chemical reductant to chemically recharge the anode.

3. The device of claim 2, wherein the source of the chemical reductant is the source of the fuel.

4. The device of claim 1, wherein the anode comprises a metal.

5. The anode of claim 4, wherein the metal has a standard reduction potential greater than -0.70 V versus the Standard Hydrogen Electrode.

6. The anode of claim 1, wherein the anode comprises at least two metals.

7. The anode of claim 6, wherein each metal has a standard reduction potential greater than -0.70 V versus the Standard Hydrogen Electrode.

8. The anode of claim 1, wherein the anode is chemically rechargeable to a reduced state from an oxidized state comprising an oxide selected from the group consisting of a metal oxide and a mixed metal oxide.

9. The device of claim 1, wherein the device is capable of producing electricity in the absence of the fuel.

10. The device of claim 1, further comprising an electrolyte in ionic communication with the anode.

11. The device of claim 10, wherein the electrolyte is a solid-state electrolyte.

12. The device of claim 11, wherein the solid-state electrolyte has a formula $(ZrO_2)(HfO_2)_a(TiO_2)_b(Al_2O_3)_c(Y_2O_3)_d(M_xO_y)_e$ where a is from 0 to about 0.2, b is from 0 to about 0.5, c is from 0 to about 0.5, d is from 0 to about 0.5, x is greater than 0 and less than or equal to 2, y is greater than 0 and less than or equal to 3, e is from 0 to about 0.5, and M is selected from the group consisting of calcium, magnesium, manganese, iron, cobalt, nickel, copper, and zinc.

13. The device of claim 12, wherein the solid-state electrolyte is selected from the group consisting of (ZrO_2), $(ZrO_2)(Y_2O_3)_{0.08}$, $(ZrO_2)(HfO_2)_{0.02}(Y_2O_3)_{0.08}$, $(ZrO_2)(HfO_2)_{0.02}(Y_2O_3)_{0.05}$, $(ZrO_2)(HfO_2)_{0.02}(Y_2O_3)_{0.08}(Ti)_2)_{0.10}$, $(ZrO_2)(HfO_2)_{0.02}(Y_2O_3)_{0.08}(Al_2O_3)_{0.10}$, $(ZrO_2)(Y_2O_3)_{0.08}(Fe_2O_3)_{0.05}$, $(ZrO_2)(Y_2O_3)_{0.08}(CoO)_{0.05}$, $(ZrO_2)(Y_2O_3)_{0.08}(ZnO)_{0.05}$, $(ZrO_2)(Y_2O_3)_{0.08}(NiO)_{0.05}$, $(ZrO_2)(Y_2O_3)_{0.08}(CuO)_{0.05}$, $(ZrO_2)(Y_2O_3)_{0.08}(MnO)_{0.05}$ and ZrO_2CaO.

14. The device of claim 10, further comprising a cathode in ionic communication with the electrolyte.

15. The device of claim 14, wherein the cathode is a solid-state cathode.

16. The device of claim 15, wherein the solid state cathode is selected from the group consisting of a metal oxide and a mixed metal oxide.

17. The device of claim 16, wherein the solid state cathode is selected from the group consisting of tin-doped In_2O_3, aluminum-doped zinc oxide and zirconium-doped zinc oxide.

18. The device of claim 16, wherein the solid state cathode is a perovskite-type oxide.

19. The device of claim 18, wherein the perovskite-type oxide has a formula $La_xMn_yA_aB_bC_cO_d$ where A is an alkaline earth metal, B is selected from the group consisting

of scandium, yttrium and a lanthanide metal, C is selected from the group consisting of titanium, vanadium, chromium, iron, cobalt, nickel, copper, zinc, zirconium, hafnium, aluminum and antimony, x is from 0 to about 1.05, y is from 0 to about 1, a is from 0 to about 0.5, b is from 0 to about 0.5, c is from 0 to about 0.5 and d is between about 1 and about 5, and at least one of x, y, a, b and c is greater than zero.

20. The device of claim 19, wherein the perovskite-type oxide is selected from the group consisting of $LaMnO_3$, $La_{0.84}Sr_{0.16}MnO_3$, $La_{0.84}Ca_{0.16}MnO_3$, $La_{0.84}Ba_{0.16}MnO_3$, $La_{0.65}Sr_{0.35}Mn_{0.8}Co_{0.2}O_3$, $La_{0.79}Sr_{0.16}Mn_{0.85}Co_{0.15}O_3$, $La_{0.84}Sr_{0.16}Mn_{0.8}Ni_{0.2}O_3$, $La_{0.84}Sr_{0.16}Mn_{0.8}Fe_{0.2}O_3$, $La_{0.84}Sr_{0.16}Mn_{0.8}Ce_{0.2}O_3$, $La_{0.84}Sr_{0.16}Mn_{0.8}Mg_{0.2}O_3$, $La_{0.84}Sr_{0.16}Mn_{0.8}Cr_{0.2}O_3$, $La_{0.6}Sr_{0.35}Mn_{0.8}Al_{0.2}O_3$, $La_{0.84}Sc_{0.16}MnO_3$, $La_{0.84}Y_{0.16}MnO_3$, and $La_{0.7}Sr_{0.3}CoO_3$, $LaCoO_3$, $La_{0.7}Sr_{0.3}FeO_3$, and $La_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_3$.

21. The device of claim 15, wherein the cathode comprises a metal.

22. The device of claim 21, wherein the metal is selected from the group consisting of platinum, palladium, gold, silver, copper, rhodium and combinations thereof.

23. The device of claim 1, wherein the device is operable at a temperature of less than about 1500 °C.

24. The device of claim 1, wherein the device is operable at a temperature of less than about 1300 °C.

25. The device of claim 1, wherein the device is operable at a temperature of less than about 1000 °C.

26. The device of claim 23, wherein the device is operable at a temperature from about 300 °C to about 1500 °C.

27. The device of claim 26, wherein the device is operable at a temperature from about 300 °C to about 1300 °C.

28. The device of claim 1, wherein the anode comprises a material selected from the group consisting of copper, molybdenum, mercury, iridium, palladium, antimony, rhenium, bismuth, platinum, silver, arsenic, rhodium, tellurium, selenium, osmium, gold, lead, germanium, tin, indium, thallium, cadmium, gadolinium, chromium nickel, iron, tungsten, vanadium, manganese, cobalt, zinc and combinations thereof.

29. The device of claim 28, wherein anode is selected from the group consisting of antimony, indium, tin, bismuth, mercury and lead.

30. The device of claim 1, wherein the anode comprises an alloy comprising at least one element selected from the group consisting of copper, molybdenum, mercury, iridium, palladium, antimony, rhenium, bismuth, platinum, silver, arsenic, rhodium, tellurium, selenium, osmium, gold, lead, germanium, tin, indium, thallium, cadmium, gadolinium, chromium, nickel, iron, tungsten, vanadium, manganese, zinc and cobalt.

31. The device of claim 1, wherein the fuel, when exposed to the anode, is in contact with the anode.

32. The device of claim 1, wherein the fuel, when exposed to the anode, is in contact with the oxidized portion of the anode.

33. The device of claim 1, wherein the source of fuel comprises a reservoir of fuel.

34. The device of claim 33, wherein the source of fuel is exposable to the anode via a guide connecting the reservoir to an inlet directed towards the anode.

35. The device of claim 1, wherein the fuel is selected from the group consisting of a carbonaceous material, sulfur, a sulfur-containing organic compound, a nitrogen-containing organic compound, ammonia, hydrogen and mixtures thereof.

36. The device of claim 35, wherein the carbonaceous material is selected from the group

consisting of conductive carbon, graphite, quasi-graphite, coal, coke, charcoal, fullerene, buckminsterfullerene, carbon black, activated carbon, decolorizing carbon, a hydrocarbon, an oxygen-containing hydrocarbon, carbon monoxide, fats, oils, a wood product, a biomass and combinations thereof.

37. The device of claim 36, wherein the hydrocarbon material is selected from the group consisting of saturated and unsaturated hydrocarbons.

38. The device of claim 36, wherein the hydrocarbon material is selected from the group consisting of aliphatics, alicyclics, aromatics and mixtures thereof.

39. The device of claim 38, wherein the hydrocarbon material is selected from the group consisting of gasoline, diesel, kerosene, methane, propane, butane, natural gas, and mixtures thereof.

40. The device of claim 36, wherein the oxygen-containing hydrocarbon is an alcohol.

41. The device of claim 40, wherein the alcohol is selected from the group consisting of a C_1-C_{20} alcohol and a combination of C_1-C_{20} alcohols.

42. The device of claim 41, wherein the alcohol is selected from the group consisting of methanol, ethanol, propanol, butanol and mixtures thereof.

43. The device of claim 1, wherein the source of the fuel comprises a variable source for at least two different fuels.

44. The device of claim 1, wherein the source of the fuel is capable of being interchanged with a different source of the fuel.

45. The device of claim 44, wherein the source of the fuel is capable of being interchanged with a different source of a different fuel.

46. The device of claim 1, wherein the device is capable of an electrical output of at least about 10 mWatt/cm^2.

47. The device of claim 1, wherein the device is capable of an electrical output of at least about 100 mWatt/cm^2.

48. The device of claim 1, wherein the device is capable of an electrical output of at least about 200 mWatt/cm^2.

49. The device of claim 1, wherein the device is self-repairing.

50. The device of claim 49, wherein the anode further comprises a sealant precursor.

51. The device of claim 50, wherein the anode comprises a sealant precursor to seal a flaw in a solid state electrolyte, when exposed to oxygen.

52. An anode being constructed of a material such that the anode is a chemically rechargeable anode.44

53. An electrochemical device, comprising:

an anode comprising a liquid, the device being operable at a temperature of no more than 1000 °C; and

a source of a fuel exposable to the anode.

54. The anode of claim 53, wherein the anode comprises a liquid.

55. The anode of claim 54, wherein the anode comprises a metal.

56. An electrochemical device, comprising:

an anode; and

an intermittent fuel source deliverable to the anode to produce a continuous electrical output from the device.

57. The device of claim 56, wherein the anode is a liquid.

58. An electrochemical device, comprising:

an anode; and

a source of a fuel exposable to the anode, the anode being constructed of a material such that the device is capable of producing electricity by using the anode in both the presence of fuel without anode consumption, and in the absence of the fuel.

59. The device of claim 58, wherein the anode is a liquid.

60. A stack of electrochemical devices, comprising:

a first and second electrochemical device, each device including an anode comprising a liquid, the anode being in ionic communication with an electrolyte and the electrolyte being in ionic communication with a cathode; and

an interconnect positioned intermediate and adjacent both the anode of the first device and the cathode of the second device.

61. The stack of claim 60, wherein the stack is substantially planar.

62. The stack of claim 60, wherein each device is substantially planar.

63. The stack of claim 60, wherein each device is tubular.

64. The stack of claim 60, wherein the devices in the stack are arranged in series.

65. The stack of claim 60, wherein the devices in the stack are arranged in parallel.

66. The stack of claim 60, wherein the stack comprises a series-parallel configuration.

67. The stack of claim 60, wherein each device is positioned within a casing.

68. The stack of claim 67, wherein each device is positioned within a casing non-permanently.

69. The stack of claim 60, wherein the stack comprises at least two devices.

70. The stack of claim 60, wherein the interconnect and cathode have thermal expansion coefficients that differ by less than about 30% at a temperature of less than about 1500 °C.

71. The stack of claim 70, wherein the thermal expansion coefficients differ by less than about 20% at a temperature of less than about 1500 °C.

72. The stack of claim 70, wherein the thermal expansion coefficients differ by less than about 10% at a temperature of less than about 1500 °C.

73. The stack of claim 70, wherein the interconnect and the cathode have the same composition.

74. A method for energy conversion, comprising:

providing an electrochemical device comprising an anode;

causing electricity to be produced in the presence of a fuel provided to the anode without anode consumption; and

causing electricity to be produced in the device in the absence of the fuel provided to the anode.

75. The method of claim 74, wherein either or both of the causing steps comprises providing an electrolyte in ionic communication with the anode and a cathode in ionic communication with the electrolyte.

76. The method of claim 75, wherein either or both of the causing steps further comprises directing an oxygen-containing gas flow to the cathode.

77. The method of claim 76, wherein either or both of the causing steps further comprises

heating the device to a temperature from about 300 °C to about 1500 °C.

78. The method of claim 77, wherein the heating produces the anode in a liquid state.

79. The method of claim 78, wherein the anode achieves the liquid state at a temperature of less than about 1000 °C.

80. The method of claim 74, wherein the an electrical output is at least about 10 mWatt/cm^2.

81. The method of claim 74, wherein the an electrical output is at least about 100 mWatt/cm^2.

82. The method of claim 74, wherein the an electrical output is at least about 200 mWatt/cm^2.

83. The method of claim 74, wherein the anode comprises a liquid.

84. The method of claim 74, wherein the device is self-repairing.

85. The method of claim 84, wherein the anode further comprises a sealant precursor.

86. The method of claim 85, wherein the anode comprises a metal and the sealant comprises a material selected from the group consisting of a metal oxide and a mixed metal oxide.

87. The method of claim 74, further comprising providing fuel to the anode to chemically recharge the anode.

88. A method for energy conversion, comprising:

providing an anode; and

delivering a fuel to the anode intermittently while producing a continuous electrical

output by using the anode.

89. A method comprising:

providing an anode;

causing a portion of the anode to be oxidized such that electricity is produced; and

exposing the oxidized portion of the anode to a chemical reductant to reduce the oxidized portion.

90. The method of claim 89, wherein the reduced portion is capable of functioning as an anode.

91. The method of claim 89, wherein the anode is a component of an electrochemical device and the chemical reductant is a fuel.

92. The method of claim 89, wherein the anode comprises a metal.

93. The method of claim 92, wherein the anode comprises a liquid.

94. The method of claim 92, wherein the oxidized anode comprises a material selected from the group consisting of a metal oxide and a mixed metal oxide.

95. The method of claim 92, wherein the metal has a standard reduction potential of greater than -0.70 V versus the Standard Hydrogen Electrode.

96. The method of claim 89, wherein the anode comprises at least two metals.

97. The method of claim 96, wherein each metal has a standard reduction potential greater than -0.70 V versus the Standard Hydrogen Electrode.

98. The method of claim 89, wherein the causing comprises providing an electrolyte in ionic communication with the anode and a cathode in ionic communication with the electrolyte.

99. The method of claim 98, wherein the causing further comprises heating the device to a temperature from about 300 °C to about 1500 °C.

100. The method of claim 98, wherein the causing further comprises exposing the anode to a fuel.

101. An electrochemical device, comprising:

a liquid anode comprising an alloy, each metal in the alloy comprising a standard reduction potential greater than -0.70 V versus the Standard Hydrogen Electrode.

102. An electrochemical device, comprising:

an anode; and

means for exposing a fuel to the anode, the anode being constructed of a material such that the device is capable of producing electricity involving the anode in both the presence of fuel without anode consumption, and in the absence of the fuel.

103. An electrochemical device, comprising:

an anode; and

means for intermittently exposing fuel to the anode to produce a continuous electrical output from the device.

104. An electrochemical device comprising:

a battery comprising an anode;

a fuel cell comprising the anode; and

a fuel comprising a material different from the anode.

105. The device of claim 104, wherein the anode is chemically rechargeable.

106. A method for energy conversion, comprising:

providing a battery; and

supplying a fuel to an anode in the battery, the fuel being of a different material than

the anode.

107. The method of claim 106, wherein the step of supplying the fuel to the anode causes the battery to switch to a fuel cell.

108. A method for energy conversion, comprising:

providing a fuel cell; and

switching the fuel cell to a battery by ceasing a supply of a fuel to an anode in the fuel cell.

109. An electrochemical device comprising at least two fuel sources for supplying at least two different types of fuel to the device, the two fuel sources being interchangeable to allow selection of a type of fuel.

110. A housing comprising a solid-state electrolyte material, the housing containing a liquid anode.

111. A method for energy conversion, comprising:

providing a device comprising a liquid metal anode; and

oxidizing a portion of the anode to form a metal oxide concurrent with the generation of electricity.

112. The method of claim 111, wherein the step of oxidizing is initiated by exposing a fuel to the anode.

113. The method of claim 111, wherein the device is operable at a temperature of less than 1000 °C.